some mineralogical properties of Seaton, Fayette, and Clinton soils in Illinois

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CONTENTS

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COVER

Electronmicrograph of clay fraction from Clintan silt loam (Sample 16419). Magnification = 15,660 ×.

SOME MINERALOGICAL PROPERTIES OF SEATON, FAYETTE, AND CLINTON SOILS IN ILLINOIS

By ROBERT L. JONES and A. H. BEAVERS[1]

Seaton, Fayette, and Clinton soils constitute a developmental sequence of relatively youthful Gray-Brown Podzolic soils developed in Wisconsin-age loess in the upper Mississippi valley. In Illinois these soils occur northward along the Mississippi River from its confluence with the Illinois River. Seaton and Fayette soils are developed in loess from 15 to 25 feet thick on Illinoian till in extreme northwest Illinois. Fayette may be developed in loess as thin as 5 feet on till or bedrock. Clinton soils are developed in loess from 8 to 15 feet thick on Illinoian till.

In general, these soils occur in the sequence Seaton, Fayette, and Clinton, with increasing distance from loess source. As might be expected, the median diameter of the loess decreases through this sequence. Structural development is most prominent in Clinton soils. Better internal drainage occurs in Seaton and Fayette soils than in Clinton. Some physical and chemical characteristics of these soils are summarized in Table 1.

The Seaton and Fayette profiles used in this study are described in Illinois Station Bulletin 587 (North Central Regional Publication 46), *Loess-Derived Gray-Brown Podzolic Soils in the Upper Mississippi River Valley* (Muckenhirn et al., 1955). This publication gives profile descriptions, mechanical analyses, exchangeable cations, and pH data. The Clinton profile was sampled in Warren County (T9N, R1W, NW, NW, NW), and is about nine miles south of the Clinton profile from Warren County (Profile No. 15) described in Bulletin 587. Mechanical analyses, pH, and organic carbon data from the Clinton profile used in this study are given in Appendix B. These data differ only in minor aspects from the Clinton profile described in Bulletin 587. Profile descriptions for the three soils are given in Appendix A.

The locations of these profiles and loess depth in the area in which these soils are developed are given in Fig. 1. The Seaton profile is 0.9 mile, the Fayette 8.2 miles, and the Clinton 24.9 miles from the Mississippi River bluff. It is apparent from the map that sediment blown by northwesterly winds from valley trains of the Iowa River would particularly influence the character of loess in this area. This part of Illinois has a mean annual rainfall of about 35 inches and a mean annual temperature of about 50° F.

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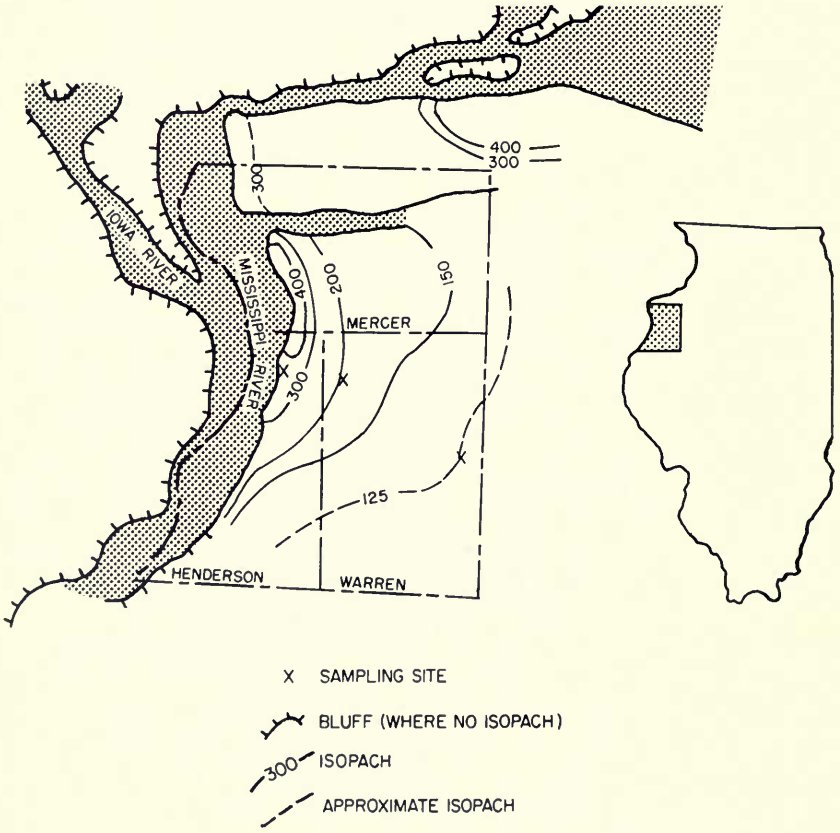
Table 1. — General Profile Characteristics of Seaton, Fayette, and Clinton Soils

	Seaton	Fayette	Clinton
Loess			
Median diameter	decreases through the sequence		
Thickness (feet)	25+	12-15	5-15
Soil Profile			
Structural development	weak	moderate	moderate to strong
Internal drainage	good	good	moderately good
Maximal B clay content	20-27	27-36	36-43
Coarse-silt—fine-silt ratio	1.5-2.5	.9-1.5	.7-.9
Exchange Ca—exchange Mg ratio	1.8-3.0	1.6-2.8	1.4-1.8



Sampling site locations and Peorian loess thickness in the sampling area. Isopachs drawn from data in the Agronomy Department files. (Fig. 1)

Loess distribution, thickness, carbonate content, and relationship to soil development in Illinois have been discussed by Smith (1942). In the area between Lomax and Dallas City, Krumbein (1937) found loess thickness followed the relationship $y = 26e^{-0.17x}$, where x is the distance from the bluff in miles. This loess-thinning relationship is different from that of Smith, who gives $y = 434 - 200 \log x$ for Peoria loess along a traverse southeast from the Illinois River. Using Smith's data, Waggoner and Bingham (1961) arrived at a log-log relationship between thickness and distance. All investigators agree that this thinning is much more rapid than a simple arithmetic regression.

Two studies have been made at the University of Illinois on the soils described here. In a study of ped surfaces and interiors, R. B. Grossman (1959) used samples from the Seaton and Fayette sites and from a Clinton site near the one reported here. From microscopic study of thin sections made from the zone of maximum clay accumulation, Grossman concluded that size of oriented clay coatings does not change significantly. However, movement and accumulation of iron to form concretions and formations of gray void peripheries and interconnections between voids by veins increase through the sequence of Seaton to Clinton. The latter venation is related to progressively stronger structural development occurring through the sequence.

In the second study, W. D. Nettleton (1958) analyzed the distribution of nitrogen in other soils and in the Seaton, Fayette, and Clinton soils used in this report. Of particular interest to the present mineralogical investigation is the fact that Nettleton found marked fluctuations in fixed ammonium above 20 inches in each of the soils. He also discovered that the ratio of B-humus nitrogen to humic acid nitrogen decreases through the Seaton to Clinton sequence. Among horizons, the ratio is highest in the A_2 or B_2.

The purpose of the study reported here is to characterize and differentiate Seaton, Fayette, and Clinton soils in west-central Illinois on the basis of certain mineralogical and chemical properties. The study also considers the effect of loess stratigraphy and transport of loess over moderate distances on mineralogical characteristics.

ANALYTICAL PROCEDURE

Mechanical Fractionation

After wet sieving to 50μ, silt fractions were obtained with the fractionator described by Beavers and Jones (1962). These fractions corresponded to 5 to 20μ (or fine silt) and 20 to 50μ (or coarse silt).

Elemental Analysis

A GE XRD-5 X-ray unit was used for spectrographic analysis. Pertinent machine-operating data are given in Table 2. Samples were prepared by mixing 6 grams of silt with 0.2 gram dried Permount, wetting the mixture with 0.6 ml of toluene, and pressing at 10,000 p.s.i. for several seconds into duplicate pellets.

Table 2. — X-Ray Machine Operating and Analytical Data

	K	Ca	Ti	Fe	Zr
Tube target.....	W	W	W	W	W
Tube voltage (kv)	50	50	50	50	50
Tube current (ma)	45	45	45	45	45
Spectral line.....	Kα	Kα	Kα	Kα	Kα
Soller slit (inches)	.020	.020	.020	.010	.010
Optical path.....	He	He	He	air	air
Analyzing crystal	LiF	LiF	LiF	LiF	LiF
Counter tube.....	FP[a]	FP[a]	P[b]	FP[a]	P[b]
Counts					
Peak.....	100 seconds	100 seconds	100 seconds	100 seconds	100,000
Background....	....	....	....	....	100,000
Standards.....	addition	addition	NBS 76, 81,102	NBS 76,81, 102, addition	NBS 76,77, 78,102

[a] FP = flow proportional.
[b] P = proportional.

X-Ray Diffraction Analysis

A GE XRD-5 X-ray unit was used for diffraction analysis. This unit utilized a copper tube operated at 50 kv and 15 ma. Semi-quantitative estimations of the principal feldspar components of several horizons were made from peak intensity measurements obtained by irradiation of ground total sample. Clay mineral analyses were made on parallel-oriented specimens prepared on ceramic slides. The method of Kinter and Diamond (1956) was followed in sample preparation, except that suction was used instead of centrifugation. Clay mineral species were identified on the basis of interpretation of glycolated samples and magnesium-saturated samples heated at 550° C. for 30 minutes. To determine the occurrence of acid labile chlorite, clay samples were heated at 70 to 90° C. in 0.2 *N* HCl for four hours. Selected magnesium- and potassium-saturated samples were parallel-oriented on glass slides and analyzed in glycolated condition.

For purposes of semi-quantitative clay mineral interpretation and profile evaluation, adjustments to solvated montmorillonite were made

by multiplying the 7A net count signal by 2 and the 10A net count signal by 3. The evaluation of chlorite to kaolinite was made on the basis of the twofold greater reflecting power of kaolinite in the 25° two-theta region. Cation exchange capacity was determined on the total clay sample with calcium as the exchangeable ion (Jackson, 1958). Calcium was estimated by flame photometer.

Calcium Carbonate Equivalent

Content of calcium carbonate or calcite was calculated from data obtained by gravimetrically determining CO_2 adsorbed on Micobite. This method is a modification of the one described by Jackson (1958).

Heavy and Light Mineral Determination

For coarse silt, the amounts of minerals occurring in the fractions greater than 2.89 sp. gr. and less than 2.30 sp. gr. were determined in duplicate by decanting from bromoform (2.89 sp. gr.) and bromoform-nitrobenzene mixtures (2.30 sp. gr.). The floating fraction was decanted after freezing the lower portion of the centrifuge tube. Three centrifugations with mixing were performed in the case of the 2.89 or heavy mineral separation. Decantation was carried out until nearly complete separation of the light mineral fraction was accomplished with 2.30 sp. gr. liquid. Large disparities for the 2.89 separation were not uncommon. Salient mineralogic characteristics of these fractions were determined by microscopic examination.

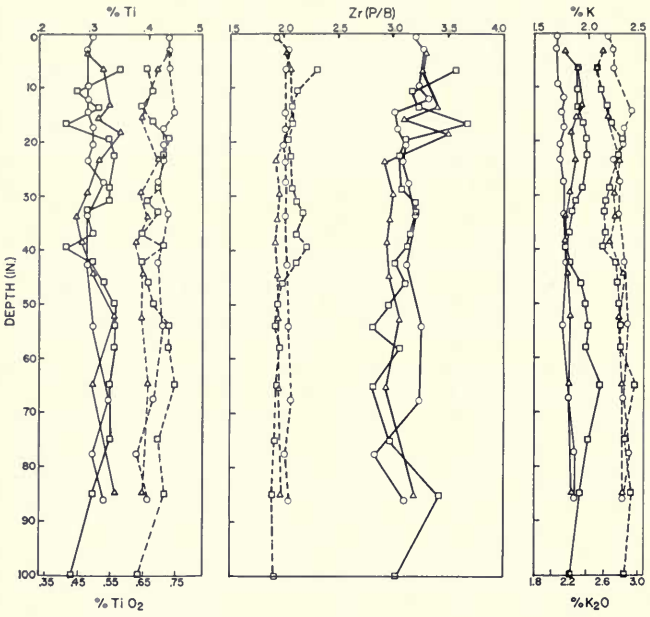
Magnetic Susceptibility

The pellet technique of Jones and Beavers (1963) was used in determining the magnetic susceptibility of the total air-dry sample. A Faraday balance was used to determine the susceptibility of the coarse-silt fraction. Mercury tetrathiocyanatocobaltate (16.44×10^{-6} cgs) served as the standard.

RESULTS AND DISCUSSION

Elemental Analysis

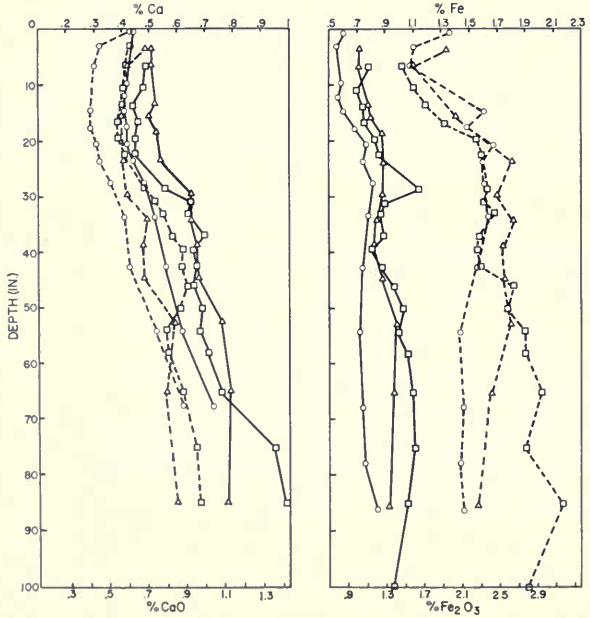
Elemental data are given in Figs. 2 and 3 and in Table 3. In general, the data are remarkable because of the few differences occurring vertically within each profile and between the three profiles. In addition to the report of concentration, peak to background ratios are given for zirconium because the ratios tend to emphasize differences in zirconium content that are not apparent in the elemental report.



Distribution of titanium, zirconium, and potassium in the fine- and coarse-silt fractions. (Fig. 2)

KEY TO FIGS. 2 AND 3

Seaton: box
Fayette: triangle
Clinton: circle
5-20μ fraction: dashed line
20-50μ fraction: solid line



Distribution of calcium and iron in the fine- and coarse-silt fractions. (Fig. 3)

Among the five elements analyzed, two or three groups of similarly behaving elements are present. Calcium and iron, particularly in the fine-silt fraction, are similar because they have undergone removal from the upper 20 to 25 inches of the profile. In contrast, titanium, potassium, and zirconium do not appear to be either concentrated or removed. Zirconium and titanium differ from potassium in the marked fluctuations occurring vertically in the profile, especially in the coarse-silt fraction and in the surficial 20 to 25 inches. Zirconium content in the fine silt and potassium content in both silt-size fractions is remarkably constant vertically.

Assuming a mobility or weathering sequence of $Fe \geq Ca > K > Ti = Zr$, some weathering trends can be found among the elemental profiles. These trends, occurring mostly below 40 to 50 inches, are most apparent in the lower B horizons. The iron profiles of both fractions are most striking in this respect. The fact that elemental analyses for Fayette tend to approach those of Seaton more than Clinton probably reflects the effect of bluff distance on weathering.

In addition to the greater potential weathering occurring with distance from loess source, the silt becomes increasingly impoverished in heavy minerals because of differential settling. The net result of differential corrasion, weathering, and sedimentation is a fine-textured sediment in which few mineralogical changes occurred at distances greater than 20 miles to windward of the bluff. However, in the zone formed by the bluff and 8 to 12 miles to leeward, great changes occur because of differential settling. The variations within the profile of zirconium and titanium in the coarse silt are interpreted as the result of differential settling of heavy minerals. Better grading of loess is apparent in the fine-silt analyses for these elements.

Data obtained by Johnson (1961) for titanium and zirconium in loess at the bluff along the Illinois and Mississippi rivers also indicate variability with depth. The latest loess, represented by the upper 20 to 30 inches, is most representative of the differential settling phenomenon, although zirconium data for coarse silt of the Seaton profile undergo changes to the depth that this profile was sampled.

These data suggest that the uppermost loess was deposited during a recent period characterized by winds of fluctuating carrying capacity. Discussions of the influence of differential settling on mineralogical characteristics of sediments formed under aqueous circumstances can be found in Rubey (1933) and Brajnikov (1944). Alternatively, it is possible that pedologic processes might give rise to these elemental differences. For example, mixing by soil fauna peculiar to the Seaton site may be invoked. However, elemental data for the other soils do not support such a pedogenic origin.

Table 3. — Elemental Analyses and Molar Ratios of the Fine- and Coarse-Silt Fractions

Depth	Horizon	Lab. No.	CaO		K_2O		TiO_2		Fe_2O_3		ZrO_2		Zr		CaO/ZrO_2		Fe_2O_3/ZrO_2		TiO_2/ZrO_2	
			5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ
(inches)			%	%	%	%	%	%	%	%	%	%	P/B	P/B	%	%	%	%	%	%
										SEATON										
4-9	A_1	17054	.73	.82	2.48	2.29	.67	.58	1.46	1.13	.05	.09	2.28	3.56	32.5	20.0	22.5	9.7	20.6	9.9
9-12	A_2	17055	.71	.81	2.56	2.29	.68	.45	1.56	.99	.05	.08	2.11	3.16	31.2	22.2	24.1	9.6	16.8	8.7
12-15	A_2	17056	.71	.76	2.61	2.29	.65	.52	1.69	1.06	.05	.09	2.06	3.27	31.2	25.4	26.1	9.0	13.5	8.9
15-18	A_2	17057	.68	.78	2.66	2.35	.68	.42	1.89	1.07	.05	.11	2.06	3.67	29.8	15.6	29.1	7.5	16.8	5.9
18-21	B_1	17058	.68	.77	2.79	2.38	.73	.55	2.22	1.17	.05	.08	2.02	3.10	29.8	21.2	34.2	11.2	22.5	10.6
21-24	B_2	17059	.71	.77	2.72	2.40	.72	.57	2.27	1.22	.05	.08	2.04	3.05	31.2	21.2	35.0	11.7	22.2	11.0
27-30	B_2	17061	.81	.92	2.65	2.35	.70	.55	2.32	1.62	.05	.08	2.06	3.06	35.6	25.3	35.7	15.6	22.2	10.6
30-32	B_2	17062	.87	1.05	2.61	2.28	.67	.55	2.29	1.27	.05	.08	2.10	3.19	38.2	28.8	35.7	12.3	21.6	10.6
32-34	B_3	17063	.91	1.04	2.60	2.23	.70	.48	2.40	1.23	.05	.08	2.16	3.19	40.0	28.6	36.9	11.9	20.6	9.3
36-38	B_3	17065	.95	1.12	2.61	2.20	.65	.50	2.24	1.26	.05	.08	2.10	3.14	41.7	30.8	34.5	12.2	21.6	9.6
38-40	B_3	17066	1.01	1.06	2.58	2.17	.72	.42	2.23	1.14	.05	.08	2.19	3.12	44.4	25.2	34.5	10.9	20.0	8.1
40-44	B_4	17067	1.01	1.08	2.71	2.20	.65	.50	2.26	1.24	.05	.08	2.10	3.00	44.4	29.7	35.0	12.0	22.2	9.6
44-48	B_4	17068	1.04	1.06	2.73	2.32	.67	.53	2.59	1.39	.04	.08	1.97	3.09	57.0	25.2	49.8	13.4	20.0	10.2
48-52	B_4	17069	.99	1.10	2.75	2.38	.68	.57	2.53	1.47	.04	.08	1.93	2.95	54.3	30.2	48.6	12.6	25.8	11.0
52-56	B_4	17070	.92	1.09	2.76	2.41	.73	.57	2.70	1.42	.04	.07	1.91	2.80	50.5	34.2	52.0	15.7	28.1	12.6
56-60	C_1	17071	.94	1.13	2.77	2.37	.73	.57	2.59	1.52	.04	.08	1.95	3.04	51.6	31.0	49.8	14.6	28.1	11.0
60-70	C_1	17072	1.01	1.20	2.92	2.54	.75	.55	2.89	1.56	.04	.07	1.93	2.80	55.4	37.7	55.7	17.2	28.9	12.1
70-80	C_1	17073	1.08	1.47	2.82	2.41	.70	.55	2.73	1.59	.04	.08	1.91	2.96	59.3	40.4	52.6	15.4	27.0	10.6
80-90	C_1	17074	1.09	1.52	2.87	2.30	.72	.50	3.10	1.52	.04	.09	1.88	3.41	59.8	37.1	59.7	13.0	27.7	8.6
95-105	C_2	17075	1.62	2.00	2.78	2.20	.63	.43	2.74	1.37	.04	.08	1.90	3.02	88.9	54.9	52.9	13.2	24.2	8.3

Table 3. — Continued

Depth	Horizon	Lab. No.	CaO		K_2O		TiO_2		Fe_2O_3		ZrO_2		Zr		CaO/ZrO_2		Fe_2O_3/ZrO_2		TiO_2/ZrO_2	
			5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ	5-20μ	20-50μ
(inches)			%	%	%	%	%	%	%	%	%	%	P/B	P/B	%	%	%	%	%	%
FAYETTE																				
2-5	A_2	17027	.68	.71	2.54	2.13	.73	.48	1.92	1.02	.04	.09	2.00	3.29	37.3	17.3	36.9	8.8	28.1	8.2
5-8	A_2	17028	.59	.71	2.48	2.17	.70	.53	1.56	1.02	.05	.09	2.04	3.25	25.9	17.3	24.1	8.8	21.6	9.1
12-14	A_3	17030	n.d.	.73	n.d.	2.22	n.d.	.55	n.d.	1.12	n.d.	.09	n.d.	3.39	n.d.	17.8	n.d.	9.6	n.d.	9.4
14-17	B_1	17031	.56	.70	2.60	2.25	.65	.52	2.02	1.13	.07	.08	2.05	3.09	17.6	19.2	22.2	10.9	14.3	10.0
17-19	B_1	17032	n.d.	.74	n.d.	2.22	n.d.	.58	n.d.	1.24	n.d.	.09	n.d.	3.50	n.d.	18.1	n.d.	10.7	n.d.	9.9
22-25	B_2	17034	.57	.76	2.76	2.26	.70	.52	2.59	1.27	.04	.08	1.90	2.91	31.3	20.9	49.8	12.3	27.0	10.0
28-31	B_2	17036	.59	.91	2.69	2.22	.65	.48	2.43	1.14	.04	.08	1.93	2.99	32.4	25.0	46.8	10.9	25.0	9.3
33-35	B_2	17038	.68	.91	2.70	2.13	.67	.45	2.60	1.20	.04	.08	1.91	2.96	37.3	25.0	50.2	11.6	25.8	8.7
37-40	B_2	17040	.67	.94	2.65	2.14	.63	.47	2.49	1.17	.04	.08	1.90	2.93	36.8	25.8	48.0	11.2	24.2	9.1
43-46	B_2	17042	.67	.95	2.79	2.17	.65	.50	2.50	1.26	.04	.08	1.92	2.95	36.8	26.1	48.0	12.2	25.0	9.6
50-55	B_2	17044	.82	1.06	2.73	2.20	.65	.57	2.57	1.40	.04	.08	1.94	3.05	45.0	29.1	49.5	13.6	25.0	11.0
60-70	C_1	17046	.78	1.10	2.78	2.19	.67	.50	2.37	1.37	.04	.08	1.94	2.93	42.8	30.2	45.5	13.2	25.8	9.6
80-90	C_1	17048	.84	1.09	2.79	2.23	.65	.57	2.23	1.33	.04	.08	1.96	3.18	46.1	30.0	43.1	12.8	25.0	11.0
100-110	C_1	17050	.85	1.15	2.78	2.20	.65	.57	2.16	1.26	.04	.09	2.01	3.22	46.6	28.1	41.5	10.8	25.0	9.8
125-140	C_1	17052	1.01	1.06	2.71	2.14	.72	.57	1.94	1.12	.04	.09	2.18	3.28	55.4	25.9	37.2	9.6	27.7	9.8
CLINTON																				
0-1	A_1	16413	.62	.60	2.63	2.06	.73	.50	1.94	.86	.04	.09	1.92	3.20	34.0	14.6	37.2	7.4	28.1	8.6
1-5	A_1	16414	.45	.60	2.67	2.05	.73	.48	1.57	.79	.05	.09	2.02	3.29	19.8	14.6	24.1	6.7	22.5	8.2
5-8	A_2	16415	.42	n.d.	2.70	n.d.	.73	n.d.	1.53	n.d.	.04	n.d.	2.01	n.d.	23.0	n.d.	29.5	n.d.	28.1	n.d.
8-11	A-B	16416	n.d.	.59	n.d.	2.07	n.d.	.48	n.d.	.83	n.d.	.09	n.d.	3.22	n.d.	14.4	n.d.	7.1	n.d.	8.2
11-13	B_1	16417	n.d.	.57	n.d.	2.12	n.d.	.48	n.d.	.80	n.d.	.09	n.d.	3.31	n.d.	13.9	n.d.	6.8	n.d.	8.2
13-16	B_1	16418	.40	.57	2.89	2.11	.75	.48	2.30	.86	.04	.08	2.00	3.00	21.9	15.6	44.3	8.3	28.9	9.3
16-19	B_2	16419	.40	.59	2.82	2.12	.72	.50	2.12	.99	.04	.08	2.00	3.03	21.9	16.2	40.9	9.6	27.7	9.6
19-22	B_2	16420	.43	.59	2.79	2.10	.72	.50	2.39	1.09	.04	.08	1.98	3.10	23.4	16.2	46.2	10.5	27.7	9.6
22-25	B_2	16421	.45	.62	2.70	2.10	.72	.48	2.29	1.06	.04	.08	2.00	3.08	24.7	17.0	44.0	10.2	27.7	9.3
25-30	B_2	16422	.50	.67	2.77	2.13	.70	.53	2.30	1.16	.04	.08	2.00	3.14	27.4	18.4	44.3	11.2	27.0	10.2
30-37	B_2	16423	.57	.73	2.73	2.13	.73	.48	2.34	1.12	.04	.09	2.00	3.20	31.3	17.8	44.9	9.6	28.1	8.2
37-48	B_3	16424	.60	.78	2.82	2.17	.70	.48	2.24	1.06	.05	.08	2.02	3.12	26.4	21.4	34.5	10.2	21.6	9.3
48-60	C_1	16425	.74	.87	2.84	2.14	.72	.50	2.06	1.02	.05	.09	2.03	3.25	32.5	21.2	31.8	8.8	22.2	8.6
60-75	C_1	16426	.87	1.02	2.81	2.19	.68	.55	2.09	1.06	.05	.09	2.05	3.23	38.2	24.9	32.3	9.0	21.0	9.4
75-80	C_2	16427	4.80	5.18	2.87	2.25	.63	.50	2.04	1.07	.04	.08	2.00	2.81	263.3	142.3	39.4	10.3	24.2	9.6
80-90	C_2	16428	2.64	2.90	2.79	2.25	.67	.53	2.09	1.20	.05	.08	2.04	3.09	116.0	79.7	32.3	11.6	20.6	10.2

The striking accumulation of calcium in the upper C_2 of Clinton probably reflects differences in dolomite content. The upper C_2 has 9.10 percent calcium carbonate equivalent (8.38 percent dolomite) as compared with 5.32 percent (4.90 percent dolomite) in the lower C_2. The absence of calcite X-ray reflections in the upper C_2 suggests that the calcium content difference is not due to authigenic secondary carbonate.

Compared with strongly developed soils in loess thinner than 75 inches (Beavers et al., 1963) in south-central Illinois, weathering as expressed by $CaO–ZrO_2$ and $Fe_2O_3–ZrO_2$ ratios in all three of these soils has not progressed very far. Therefore, on the basis of elemental data, it appears warranted to classify these soils as youthful.

Clay Mineralogy

The clay mineralogy of these soils is similar. The distributions of montmorillonite, illite, and kaolinite plus chlorite are given in Table 4. Representative diffractograms of potassium- and magnesium-saturated samples are reproduced in Fig. 4. Much greater changes occur vertically within the profiles than between the profiles. In general, the clay contents are comparable to those reported by Glenn et al. (1960) for Tama silt loam in southwestern Wisconsin and Frye et al. (1962) for Peorian loess along the Mississippi River north of Alton, although the minerals are not defined consistently among the reports. Caldwell et al. (1955) reported predominance of montmorillonite and accessory illite, kaolinite, and quartz in the less than 0.5μ fraction of two Fayette soils developed in Peorian loess in Minnesota.

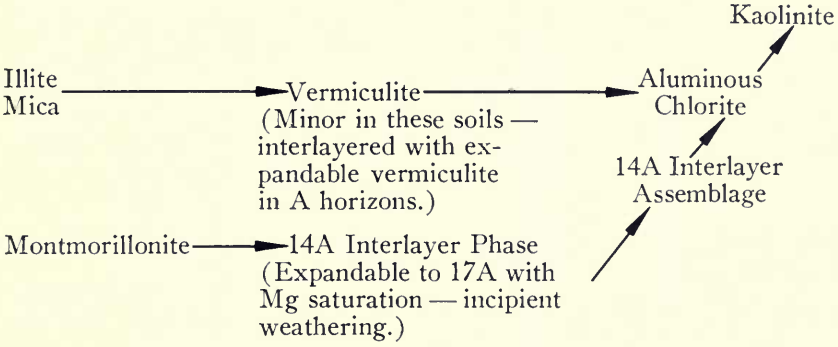
Montmorillonite, probably approaching nontronite in composition, undergoes marked destruction from C horizons upward to surficial horizons of these soils. The course of montmorillonite transformation is best observed in the potassium-saturated and glycol-solvated samples. Throughout the profiles, and especially in the Clinton profile, where there may be influence of underlying Illinoian till, vermiculite formation is indicated by the collapse of expandable minerals to 10A on K saturation. The precursor of this vermiculite is not certain but may be illite and larger ($>2\mu$) mica particles.

There is evidence of aluminum interlayer formation of the montmorillonite-type minerals in the B horizons of the Seaton and Clinton profiles. This interlayer assemblage gives a 14A component on both potassium and magnesium saturation. In the lower B horizon, "degraded" montmorillonite expands to 17A when magnesium-saturated and glycolated. This behavior is similar to that reported by Pawluk (1963) for interlayer minerals in podzols of Alberta. Upon heating, all diffractograms with interlayer minerals showed marked "shoulders"

on the low angle side of 10A. This interlayered mineral assemblage also occurs in the upper B of Fayette (not shown in Fig. 4).

The absence of a rational reflection for montmorillonite and the occurrence of a complex interlayered species (10A + 14A + 17A) is particularly apparent in the magnesium-glycolated samples of surface horizons. Because the A horizons undoubtedly have clay minerals contributed as loess and dust over a long period of recent time, the interpretation of the diffractograms relative to underlying materials is difficult.

The following weathering scheme is suggested for clay minerals in these soils (cf. Jackson, 1963):



Formation of the 14A intergrade seems to be closely associated with unimpeded or good internal drainage of these soils. This intergrade mineral occurs to over 30 inches' depth in Seaton, and is confined to the upper 10 inches of the other two soils.

Electronoscopic examination of clay from the B_2 of Clinton (Sample 16419) indicates that a planar habit is the most common shape present.

Cation exchange capacity (Table 4) of the clay fraction does not appear to vary consistently with weathering within the profiles. On the average, the clay fraction within the sola has approximately 55 to 65 me./100 grams exchange capacity. Higher exchange capacities in the A horizons may be due to resistant organic matter. The trend of weathering of clay minerals should lower the capacity of the total clay fraction.

Heavy and Light Mineral Determination

The content of heavy minerals in selected horizons is given in Table 5. Even allowing for the imprecision of the heavy-mineral separation technique, several trends are apparent from the data. As expected, heavy-mineral content decreases below 20 inches in the profile from Seaton to Clinton, or with distance from the bluff. This is con-

sistent with the elemental data for iron. The similar TiO_2–ZrO_2 ratios (coarse silt) indicate that the same ratios of heavy minerals, in this case rutile and zircon, seem to be deposited at all three sites.

Table 4. — Diffraction Analysis of Crystalline Clay Minerals[a] in the Less than 2μ Fraction and Cation Exchange Capacity (C.E.C.) of Selected Samples

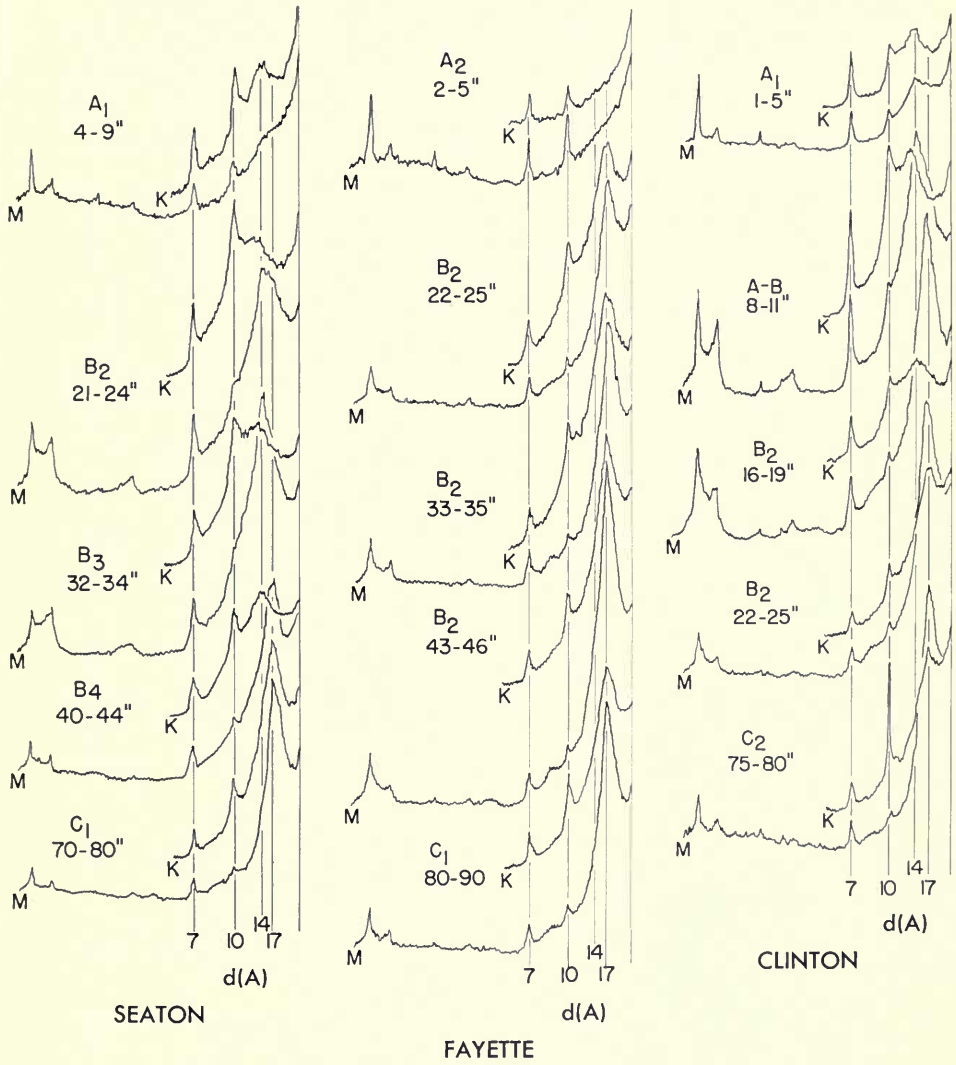
Depth	Horizon	Lab. No.	Clay Minerals			
			Kaolinite Chlorite	Illite	Mont-morillonite[b]	C.E.C.
(inches)			%	%	%	me./100 g. clay
			SEATON			
4-9	A1[c]	17054	([d])			70
12-15	A2[c]	17056	([d])			
21-24	B2	17059	18	42	40	64
27-30	B2	17061	20	27	53	
32-34	B3	17063	14	30	56	75
34-36	B3	17064	19	29	52	
36-38	B3	17065	12	31	57	
40-44	B4	17067	13	23	68	
48-52	B4	17069	9	27	64	
56-60	C1	17071	9	31	60	
70-80	C1	17073	7	23	70	76
			FAYETTE			
2-5	A2[c]	17027	22	63	15	55
5-8	A2	17028	31	52	17	
14-17	B1	17031	24	40	36	
22-25	B2	17034	15	35	50	60
28-31	B2	17036	12	31	57	
31-33	B2	17037	13	35	52	
33-35	B2	17038	13	29	58	57
35-37	B2	17039	11	32	57	
37-40	B2	17040	15	30	55	
43-46	B2	17042	11	26	63	
50-55	B2	17044	13	31	56	
60-70	C1	17046	12	22	66	
80-90	C1	17048	13	26	61	55
			CLINTON			
1-5	A1[c]	16414	23	55	22	82
5-8	A2[c]	16415	23	56	21	
8-11	A-B	16416	17	41	42	45
16-19	B2	16419	16	35	49	
22-25	B2	16421	14	29	57	57
30-37	B2	16423	12	24	64	
48-60	C1	16425	12	34	54	
75-80	C2	16427	11	31	58	85

[a] Calculated for the purpose of comparing profiles. Results are to be interpreted in only a semiquantitative manner.

[b] Includes 14A intergrade and "degraded" montmorillonite.

[c] Treated with H_2O_2 prior to dispersion. All samples oxidized before cation exchange determination.

[d] Characteristics of diffractograms prevented quantitative determination (see Fig. 4).



X-ray diffraction patterns of clay-size separates from selected horizons. (Fig. 4)
K = potassium-saturated and glycolated
M = magnesium-saturated and glycolated
Recording is linear.

Seaton and Fayette are generally lower in heavy mineral content above 20 inches (Table 5 and Fig. 5). This fact is indicative of weathering and surficial Recent loess. Throughout the Clinton profile there appears to be little variation in heavy-mineral content. Although samples from closer intervals were used for the Seaton and Fayette profiles, more vertical variation of heavy minerals appears to occur in these soils. This variation is also consistent with the elemental analyses and magnetic susceptibility data for Seaton and Fayette. Contrast between vertical variation in these soils is undoubtedly indicative of grading. The best graded material occurs at the Clinton site.

The most salient mineralogical characteristics of the heavy-mineral fraction as determined microscopically are as follows: (1) There is no significant difference in mineralogy within or between profiles. (2) Opaque minerals constitute approximately half of this fraction. (3) Opaque minerals are principally leucoxene and surficially oxidized (or hematitic) magnetite, and less than one-third of the opaque minerals are black metallics. (4) Amphibole constitutes about half of the non-opaque or translucent suite. (5) Other prominent translucent minerals in the order of their occurrence are tourmaline > pyroxene > biotite-muscovite > chlorite = zircon = garnet > staurolite = actinolite = rutile. (6) Micas have marginal birefringence even in the calcareous horizons.

Among the many mineralogical features, it is interesting to note that Glenn et al. (1960) found that amphibole is abundant in the heavy-mineral fraction of the C horizon of a Tama profile in southwestern Wisconsin. The alteration of ilmenite to leucoxene, the oxidation of magnetite, and the weathering of the micas under acid and alkaline conditions are striking.

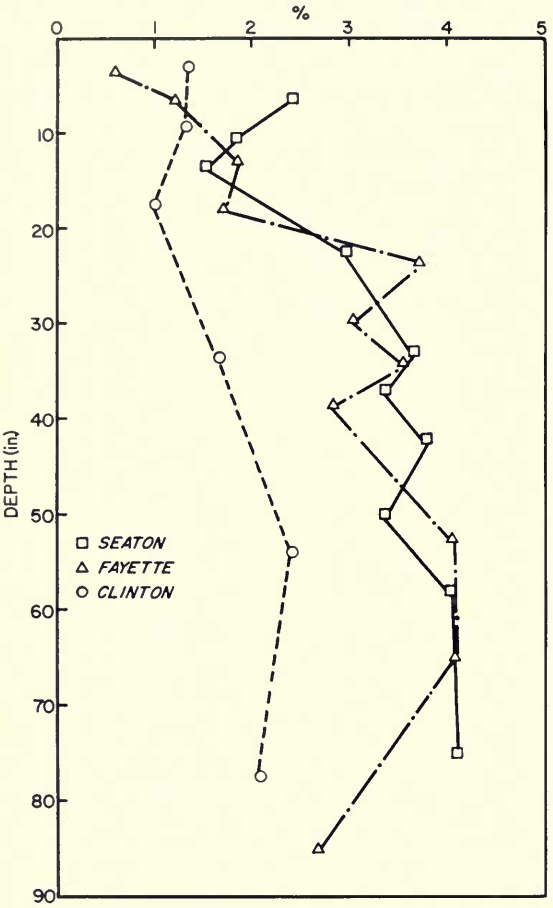
Frye, Glass, and Willman (1962) report much less opaque minerals in the fine- and very fine-sand fractions of Peoria loess along the Mississippi River north of Alton than is found in the coarse silt of the Seaton, Fayette, and Clinton soils. However, they report as much as 60 percent amphibole in the sand fraction (62-250μ). This percent is comparable to that found in the coarse-silt fraction.

X-ray diffraction analyses of the total sample indicate that minerals approaching albite and microcline in composition are the principal feldspar components of the C horizons of these soils. The amount of albite is particularly striking (Table 6). Frye et al. (1962) found more potassic feldspar (16 percent) than plagioclase feldspar (9 percent) in the sand fraction of Peoria loess along the Mississippi River north of Alton, Illinois. Diffraction data also indicate that calcareous horizons are composed predominantly of dolomite.

Table 5. — Heavy-Mineral Content of 20 to 50μ Fraction and Magnetic Susceptibility of Total Soil and 20 to 50μ Fraction

Depth	Horizon	Lab. No.	Xg total	Xg 20-50μ	Heavy minerals	
					20-50μ	total[a]
(inches)			$\times 10^{-6}$ cgs	$\times 10^{-6}$ cgs	%	%
			SEATON			
4-9	A_1	17054	22.6	n.d.	2.41	1.18
9-12	A_2	17055	23.0	19.4	1.94	1.01
12-15	A_2	17056	n.d.	22.6	1.52	.89
15-18	A_2	17057	21.9	n.d.	n.d.	n.d.
18-21	B_1	17058	n.d.	24.6	n.d.	n.d.
21-24	B_2	17059	22.8	21.6	2.96	1.60
27-30	B_2	17061	22.4	29.2	n.d.	n.d.
32-34	B_3	17063	26.1	n.d.	3.66	1.96
36-38	B_3	17065	22.1	29.2	3.37	1.92
40-44	B_4	17067	22.4	31.5	3.78	2.25
48-52	B_4	17069	23.9	31.8	3.35	1.84
56-60	C_1	17071	21.9	32.7	4.02	2.23
70-80	C_1	17073	25.7	29.6	4.10	2.39
95-105	C_2	17075	17.2	26.5	n.d.	n.d.
			FAYETTE			
2-5	A_2	17027	19.8	20.1	.60	.30
5-8	A_2	17028	n.d.	n.d.	1.21	.64
12-14	A_3	17030	20.2	22.4	1.88	.92
17-19	B_1	17032	18.4	30.1	1.70	.73
22-25	B_2	17034	15.0	26.7	3.71	1.51
28-31	B_2	17036	18.1	31.8	3.04	1.24
33-35	B_2	17038	n.d.	n.d.	3.52	1.50
37-40	B_2	17040	16.7	22.1	2.81	1.14
43-46	B_2	17042	13.8	27.6	n.d.	n.d.
50-55	B_2	17044	17.5	26.7	4.02	1.55
60-70	C_1	17046	16.9	27.1	4.06	1.62
80-90	C_1	17048	15.6	22.1	2.69	1.22
100-110	C_1	17050	12.8	19.2	n.d.	n.d.
125-140	C_1	17052	5.3	5.0	n.d.	n.d.
			CLINTON			
1-5	A_1	16414	11.2	9.2	1.35	.60
8-11	A-B	16416	12.3	10.0	1.32	.54
13-16	B_2	16418	10.1	10.1	n.d.	n.d.
16-19	B_1	16419	n.d.	9.9	1.04	.29
19-22	B_2	16420	9.6	n.d.	n.d.	n.d.
25-30	B_2	16422	11.9	16.5	n.d.	n.d.
30-37	B_2	16423	11.8	18.5	1.67	.55
48-60	C_1	16425	9.8	11.0	2.40	.89
60-75	C_1	16426	8.3	8.8	n.d.	n.d.
75-80	C_2	16427	4.0	5.8	2.08	.72
80-90	C_2	16428	3.9	5.8	n.d.	n.d.

[a] Percent heavy minerals in 20-50μ $\times$ percent 20-50μ in soil.



Heavy-mineral content (>2.89 sp. gr.) of the coarse-silt fraction. (Fig. 5)

Table 6. — Relative Contents of Feldspar and Carbonate Minerals in Deep Horizons

Depth	Horizon	Lab. No.	Feldspar content	Carbonate
(inches)		SEATON		
80-90	C_1	17074	Microcline > Albite	None
90-105	C_2	17075	Albite ≥ Microcline	Dolomite
		FAYETTE		
100-110	C_1	17050	Albite > Microcline	None
125-140	C_1	17052	Albite > Microcline	None
		CLINTON		
75-80	C_2	16427	Albite = Microcline	Dolomite
80-90	C_2	16428	Albite = Microcline	Dolomite

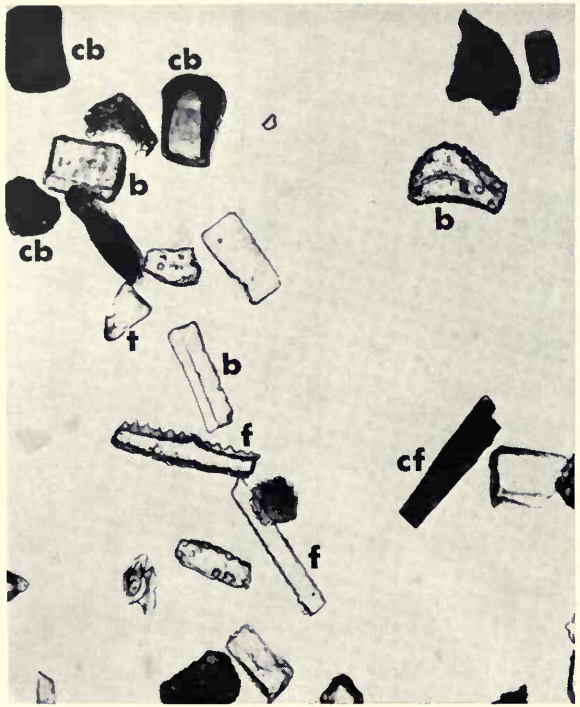
The light-mineral distribution of these soils (Table 7) indicates an almost linear decrease of plant opal from the surface to 20 inches, where opal makes up 0.10 percent by weight or less. Seaton and Fayette appear to have higher opal contents at depth, and Seaton has the highest opal content throughout. This distribution is consistent with an interpretation involving slow deposition of Recent loess on a sparsely grassed landscape. Higher opal content at depth would be expected near the bluff — for example, at the Seaton site — than at a distance because of the loess thickness-distance relationship. Other evidence for such a Recent loess has been cited by Beavers et al. (1962) and by Jones and Beavers (1963).

Table 7. — Plant Opal Content of Selected Horizons

Depth	Horizon	Lab. No.	Opal content
(inches)			%
SEATON			
4-9	A_1	17054	.51[a]
12-15	A_2	17056	.31
18-21	B_1	17058	.10
FAYETTE			
2-5	A_2	17027	.32
5-8	A_2	17028	.18
12-14	A_3	17030	.21
17-19	B_1	17032	.06
CLINTON			
0-1	A_1	16413	.44
1-5	A_1	16414	.33
13-16	B_1	16418	.05

[a] Percent light minerals in 20-50μ × percent 20-50μ in soil.

In addition to graminous opal represented principally by infillings of fundamental, bulliform, and trichome cells, occasional fragmented opaline monactine sponge spicules occur in the light-mineral concentrate (Fig. 6). These spicules are probably of Recent age, and were derived from sponge fauna inhabiting the upper Mississippi drainage. The opaline tests of the radiolarian *Dictyomitra* was found in the C_1 of Seaton. Jones, Hay, and Beavers (1963) reported this and other microfossils in loess of Illinois, and indicated that the fossils were derived from Cretaceous rocks in the northern Great Plains. *Dictyomitra* in Seaton probably had such an origin — being blown from a valley train after reworking and transport from the west.



Photomicrographs of opaline microfossils in the coarse-silt fraction from Clinton (Sample 16414). Magnification = 250 ×. (Fig. 6)

b = bulliform cell
cb = carbonaceous bulliform cell
f = fundamental cell
cf = carbonaceous fundamental cell
t = trichome or "prickle" cell
s = opaline sponge spicule

Magnetic Susceptibility

Magnetic susceptibility data for total sample and for the coarse-silt fraction are given in Table 5. In general, the susceptibility data are consistent with heavy mineral and elemental data, indicating marked fluctuations in mineralogy of the upper solum in both Seaton and Fayette. Better grading of the loess is suggested by a rather uniform susceptibility content throughout the Clinton profile.

Decrease of susceptibility of the total sample from Seaton to Clinton is partly attributable to decrease in mean particle size of the ferrimagnetics. This decrease in mean particle size reduces the overall susceptibility of the total sample. However, this effect is thought to be subordinate to the other processes described above. The slightly poorer drainage of Clinton also causes lower susceptibility values.

SUMMARY

Because of the differences in loess depth between Seaton, Fayette, and Clinton soils, the age of the loess in which these soils are developed probably varies markedly. Using the 22,000 year B.P. date of Frye et al. (1962) for the base of Peoria loess, the Clinton solum has developed in Peoria loess deposited principally from 22,000 to about 11,000 years B.P. Evidence has also been presented that a veneer of Recent loess deposited since 11,000 years B.P. is present in the surface. At the Seaton and Fayette sites the sola are developed in much thicker Recent loess and much younger Peoria loess. The titanium and zirconium analyses and the TiO_2–ZrO_2 ratio indicate that the Peoria loess is fairly uniform in composition below 20 inches to the depth sample for the three soils.

Elemental analyses, heavy-mineral analyses, and magnetic susceptibility data indicate that upper portions of the sola of Seaton, Fayette, and Clinton soils of northwestern Illinois are developed in Recent loess. Vertical variability of the parameters measured in Seaton and Fayette soils and relatively uniform analyses for the Clinton soil suggest that grading is important in interpretation of mineralogical characteristics of these loessial soils.

The upper portions of the sola are low in calcium and iron content in the 5 to 20μ and 20 to 50μ fractions. This is probably indicative of leaching loss, and possibly a reflection of deposition of a Recent loess blanket poor in these elements. Calcium and iron are also among the first elements to weather in these relatively youthful soils, particularly in the fine-silt fraction. Iron-zirconium and calcium-zirconium ratios suggest similar weathering of these elements. Titanium-zirconium ratios indicate similar proportions of minerals bearing these elements.

Heavy-mineral and magnetic susceptibility data indicate a decrease in the heavy-mineral fraction with distance from the bluff or loess source. The forces of grading are invoked to explain this decrease, although progressive weathering through the soil sequence is not entirely discounted. Distribution of plant opal with depth substantiates the depth-distribution pattern; that is, opal is distributed deepest in soils at the bluff. Clay mineral weathering is closely related to internal drainage, and is expressed by progressive formation of a 14A aluminous intergrade mineral derived from montmorillonite upward in the profile. Mica and illite weather to vermiculite throughout the profile.

Deposition of Recent loess that is somewhat weathered before deposition complicates interpretation of the mineralogy and weathering of the surficial horizons of these soils. Recognition of this relationship is important, and some of the hypotheses for weathering based on studies in the upper Mississippi Valley and elsewhere may need to be reevaluated in light of it. Contrary to physical appearance, loess need not be uniform in mineralogy either vertically within the section or with distance from source.

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APPENDIX A: PROFILE DESCRIPTIONS

Clinton Silt Loam

Warren County, T9N, R1W, Sec. 2, NW¼, NW ¼, NW ¼. Sampled on east side of gravelled road at first cut south of section line by R. T. Odell and G. D. Smith (November 19, 1940). Colors determined on air-dry crushed samples by R. L. Jones, May, 1963. This description follows the style and format of the descriptions in Illinois Agricultural Experiment Station Bulletin 587 (North Central Regional Publication 46).

Horizon	*Depth (inches)*	*Sample No.*	*Munsell Color Notation*	*Description*
A_0	0-1	16413	10YR 5/2	Brown leaf mould.
A_1	1-5	16414	10YR 6/2	Platy friable silt loam.
A_2	5-8	16415	10YR 6/3	
	8-11	16416	10YR 6.5/3	
B_1	11-13	16417	10YR 6.5/4	Gray-coated, weakly nut-like.
B_2	13-16	16418	10YR 6.5/4	Subangular nut-like structure
	16-19	16419		coated with yellow and gray specks.
	19-22	16420	10YR 6.5/4	Aggregates ½ to ¾ inch in up-
	22-25	16421		per part, increasing to 1½ inch
	25-30	16422		in lower part.
	30-37	16423	10YR 6.5/4	Blocky.
	37-48	16424	10YR 7/4	
C_1	48-60	16425	10YR 6/4	Nearly massive.
	60-75	16426	10YR 6/4	
C_2	75-80	16427	10YR 7/4	
	82-90	16428	10YR 7/4	
D	94+			Dark Illinoian till soil.

Seaton Silt Loam

Henderson County, T11N, R4W, Sec. 8, NW ¼, NW ¼, NE ¼. Sampled on east side of road 24 rods north of intersection. Six-percent slope to south. The following description is somewhat modified from that written by R. B. Grossman, July 30, 1957. Colors are for moist conditions and, unless otherwise noted, refer to the ped surface. Sampled within several rods of the site sampled for Illinois Bulletin 587 (Profile No. T40). This description follows a more modern format than those in Bulletin 587.

Horizon	*Depth (inches)*	*Description*
A_1	0-5	Dark brown (10YR 3/3) friable silt loam; weak fine-crumb structure; clear boundary.
A_2	5-10	Brown (10YR 4.5/3) soft to slightly hard silt loam; weak to moderate fine-platy structure; clear boundary.
A_3	10-15	Light yellowish-brown (10YR 6/4) and dark brown (7.5YR 4/3) hard silt loam, breaking to yellowish-brown (10YR 5/4) ped interior; moderate to strong, fine to medium subangular blocky structure; clear boundary.

B_1	15-20	Yellowish-brown (10YR 6/4) with some dark brown (7.5YR 4/3) hard silt loam, breaking to yellowish-brown (10YR 5/4) ped interior; moderate to strong, fine to medium subangular blocky structure; clear boundary.
B_{21}	20-26	Dark brown (7.5YR 4/3) and yellowish-brown (10YR 6/4) hard to very firm silt loam, breaking to brown (7.5YR 5/5) ped interior; moderate to strong, medium to fine, blocky to subangular blocky structure; clear boundary.
B_{22}	26-33	Brown (7.5YR 4/3) firm to very firm silt loam, breaking to yellowish-brown (10YR 5/4) ped interior; strong medium blocky structure; gradual boundary.
B_3	33-43	Brown (7.5YR 4/3) firm to very firm silt loam with few light yellowish-brown (10YR 6/4) mottles on vertical faces, breaking to brown (10YR 5/3) ped interior; weak to moderate, medium to coarse prismatic structure; gradual boundary.
C_1	43-66	Dark brown (7.5YR 4/2) firm to friable silt loam, breaking to brown (10YR 4/3) ped interior; weak, very coarse prismatic structure.

Fayette Silt Loam

Warren County, T11N, R3W, Sec. 9, NE ¼, NE ¼, SE ¼. Sampled 27 rods west of bridge and 9 rods west of top of slope. Six-percent slope to southwest. Colors are for moist conditions and, unless otherwise noted, refer to the ped surface. Sampled within several feet of the site sampled for Bulletin 587 (Profile No. T39). This description is somewhat modified from that written by R. B. Grossman, August 29, 1957.

Horizon	*Depth (inches)*	*Description*
A_{11}	0-4	Very dark grayish-brown (10YR 3/2) very friable silt loam; weak fine-crumb structure; clear boundary.
A_{12}	4-7	Brown (10YR 5/3) very friable silt loam; weak fine-platy structure; clear boundary.
A_{21}	7-13	Brown (10YR 5/3) very friable to soft silt loam; moderate fine-platy structure; clear boundary.
A_3	13-15	Light yellowish-brown (10YR 6/4) mottled dark brown (7.5YR 4/2) firm silt loam, breaking to yellowish-brown (10YR 5/4) ped interior; moderate fine subangular-blocky-to-platy structure; clear boundary.
B_1	15-20	Light yellowish-brown (10YR 6/4) mottled brown (7.5YR 4/2) firm silt loam, breaking to yellowish-brown (10YR 5/4) ped interior; fine subangular blocky to blocky structure; clear boundary.
B_{21}	20-30	Dark brown (7.5YR 4/2) with some gray (10YR 7/2, dry) firm to very firm silt loam, breaking to yellowish-brown (10YR 4.5/4) ped interiors; strong medium to fine blocky structure; gradual boundary.

B_{22}	30-39	Dark brown (7.5YR 4.5/2) with some light gray (10YR 7/1, dry) very firm silt loam, breaking to brown (10YR 5.5/3) ped interior; prismatic structure, breaking to strong medium to coarse blocky structure; gradual boundary.
B_3	39-53	Brown (7.5YR 5/2) very firm silty clay loam, breaking to brown (10YR 5.5/3.5) ped interiors with common fine, faint yellowish-brown mottles; strong medium prismatic structure, breaking to moderate to strong, coarse blocky structure; diffuse boundary.
C_1	53-72	Brown (7.5YR 5/3) fine silt loam, breaking to light yellowish-brown (10YR 6/4) ped interior with common, medium, faint brownish-yellow and very pale brown mottles; moderate to strong coarse prismatic structure.

Clinton Silt Loam

Warren County, T11N, R1W, Sec. 21, NW ¼, NW ¼, 35 rods south of fence and 11 rods east of road center. Five-percent slope to southwest. Colors are for moist condition and, unless otherwise noted, refer to the ped surface. The following description is somewhat modified from that written by R. B. Grossman, August 31, 1957. Note that this profile is 9 miles north of the Clinton used in the mineralogic study. The profile is thought to be from the same pit as the soil described in Illinois Bulletin 587 (Profile No. 15).

Horizon	*Depth (inches)*	*Description*
A_1	0-4	Dark gray (10YR 4/1) friable silt loam; weak fine-crumb to platy structure; clear boundary.
A_2	4-10	Pale brown (10YR 6/3) friable silt loam; weak fine to very fine platy structure; clear boundary.
A_3	10-13	Pale brown (10YR 6/3) firm silt loam, breaking to yellowish-brown (10YR 5/4) and dark yellowish-brown (10YR 4/4) ped interior; moderate fine subangular to coarse platy structure; very vesicular; clear boundary.
B_1	13-18	Pale brown (10YR 6/3) and brown (10YR 4/3) firm to very firm silt loam, breaking to yellowish-brown (10YR 5/4) ped interior; strong fine-subangular-blocky structure; clear boundary.
B_{21}	18-26	Dark grayish-brown (8.75YR 4/2) and pale brown (10YR 6/3) very firm silty clay loam, breaking to yellowish-brown (10YR 5/4) and dark grayish-brown (8.75YR 4/2) ped interior; strong fine to medium blocky structure; weakly vesicular; clear boundary.

B_{22} 26-38 Dark brown (7.5YR 4/2) and pale brown (10YR 6/3) very firm silty clay loam, breaking to yellowish-brown (10YR 5/4) ped interior with dark brown (7.5YR 4/2) coatings; strong medium blocky structure with tendency to prismatic; clear boundary.

B_3 38-48 Dark brown (7.5YR 4/2) and pale brown (10YR 6/3) extremely firm silty clay loam, breaking to yellowish-brown (10YR 5/4) ped interior with many medium distinct yellowish-brown and very pale brown mottles; strong medium-to-coarse prismatic structure; moderately vesicular; gradual to diffuse boundary.

C_1 48-68 Dark brown (7.5YR 4/2) very hard silt loam, breaking to brown (10YR 5/3) ped interior with many medium distinct yellowish-brown and light brownish-gray mottles and a few Fe-Mn concretion-like mottles; weak, very coarse prismatic structure; very vesicular.

APPENDIX B: ANALYTICAL DATA

Mechanical Analysis, Organic Carbon, and pH Data for Clinton Silt Loam[a]

Sample No.	Depth	Sand 50μ	Silt 2-20μ	Fine silt 2-20μ	Clay 2μ	Organic carbon	pH
	inches	%	%	%	%	%	
16413	0-1	1.0	78.2	38.0	16.2	3.38	5.4
16414	1-5	.9	85.1	40.4	12.8	1.01	4.2
16415	5-8	1.0	83.6	40.2	15.4	.50	4.2
16416	8-11	.6	78.2	37.6	21.2	.38	4.1
16417	11-13	.6	72.8	36.7	26.1	.31	4.2
16418	13-16	.5	65.1	35.4	34.4	.31	4.2
16419	16-19	.4	63.1	35.2	36.4	.27	4.1
16420	19-22	.4	62.8	35.6	36.3	.26	4.2
16421	22-25	.5	64.4	36.9	35.1	.24	4.3
16422	25-30	.4	66.8	38.8	32.5	.23	4.3
16423	30-37	.3	69.7	36.8	30.0	.19	4.4
16424	37-48	.6	71.2	36.7	28.1	.20	4.6
16425	48-60	.7	72.7	35.5	26.3	.19	4.9
16426	60-75	1.2	74.4	35.7	23.3	.18	5.7
16427	75-80	.8	81.3	46.5	14.4	[b]	7.3
16428	80-90	.6	76.9	50.7	16.2	[b]	7.4

[a] Presentation of these data follows that of Illinois Agricultural Experiment Station Bulletin 587 (N. C. Regional Publication No. 46).
[b] Calcareous.

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